ELECTRICAL PROTECTION FUNDAMENTALS

CONTENTS

1. GENERAL

1.1 This section provides REA borrowers, engineers, and other interested parties with information for use in the design, construction, and operation of REA borrowers' telephone systems. It discusses conditions which require electrical protection and outlines, in general, recommended protective measures. It replaces Issue 2, dated November 1955. The purpose of this revision is to up date the section by emphasizing conditions which apply to modern telephone plant and to simplify the arrangement of material presented. Details on specific types of protection can be found in other sections of the 800 series of the TE & CM.

1.2 Telephone systems are subject to disturbances from external sources of electrical energy. These sources include electric power supply circuits and natural phenomena, such as lightning and low energy static effects. The effects in the telephone plant may be confined to interference with its normal use or operation, as in the case of noise or interference with signaling; or they may be capable of creating hazards to subscribers, the public, telephone personnel, and plant.

1.3 As will appear in subsequent sections, some protective measures are intended to be effective primarily against lightning and others are intended primarily to avoid or minimize trouble resulting from electric power systems. Most protective measures afford some degree of protection against both lightning and electric power systems.

1.4 Other TE & CM sections which discuss electrical protection are the following:

805 Subscriber Station Protection
810 Electrical Protection of Central Office Equipment
815 Electrical Protection of Aerial Cable
816 Electrical Protection of Buried Plant

820 Open Wire Circuit Protection
821 Multipair Distribution Wire Protection
822 Electrical Protection of Carrier Equipment
823 Use of Gas Tube Arresters
825 Situations Requiring Special Protection
830 Electrical Protection Assembly Units

1.5 Protection equipment, in general, should possess sufficient voltage or current sensitivity so that it will operate when conditions require but, at the same time, it should not be so sensitive as to cause excessive service interruptions. It is not practicable to install and maintain protection equipment to prevent all damage. Hence, even with a properly designed protection system, some damage may be expected when unusually severe disturbances occur.

1.6 Prior to considering protective measures for use in a particular telephone system, the engineer should familiarize himself with the various types of protective devices described in the above-mentioned sections in order to determine which devices to utilize to meet normal and special situations.

2. COMMON SOURCES OF ELECTRICAL DISTURBANCES

2.1 Lightning

2.11 Lightning is a transient high current electrical discharge. It occurs when some region of the atmosphere attains an electrical charge of sufficient potential to cause dielectric breakdown of the air.

2.12 The most common source of lightning is the thundercloud. Within a typical thundercloud there is a turbulent interaction of wind, water, and ice in the presence of a gravitational field and temperature gradient. From the interaction of these elements charged regions of the thundercloud emerge as shown in Figure 1. This concentration of charge induces a similar, but opposite, concentration of charge in earth beneath the cloud, in another portion of the same cloud, or in another cloud. When the electric field gradient exceeds the dielectric strength of the air, lightning discharges, cloud-to-cloud, within a cloud, or cloud-to-ground, take place as shown in Figure 1.

2.13 A complete lightning stroke may last as long as $\frac{1}{4}$ second, and consist of several periods of high current discharge separated by periods of up to one tenth of a second when current flow is significantly reduced. Figure 2 is a current-time plot of a typical lightning discharge.

2.14 The crest current magnitude of an actual lightning stroke varies widely. Figures 3A and B are curves illustrating the crest current for direct lightning strokes to aerial and buried structures. It should be noted that the average stroke is about 16KA in the case of aerial

structures and about 30KA for buried. While these currents are large, it should be remembered that these values are for direct strokes. Typical surges conducted or induced into telephone facilities would be considerably smaller. Ordinarily, the energy in a direct stroke is so great as to make protective measures unfeasible and uneconomical for normal telephone plant. However, it is possible to engineer radio towers and similar structures to withstand most direct strokes.

2.15 In addition to direct strokes, telephone outside plant facilities may be subjected to lightning caused potentials in the following manners:

2.151 Induction from nearby strokes to earth.

2.152 Arcing to plant from a point where a stroke terminates in the earth, on a tree, or similar structure.

2.153 Lightning currents may also be conducted to telephone plant when strokes take place near grounded points on the telephone system. For example, a stroke to ground near a subscriber's station will raise the earth potential at the station protector so that surge currents will flow from the protector ground, through the protector, to other ground points outside the direct influence of the stroke.

2.16 Some types of damage resulting directly or indirectly from lightning are: Personal shock, fires at subscriber stations or central offices, fusing or severing of conductors, dielectric failures and burns in cables, permanent grounding of protectors and the failure of solid state electronic equipment such as carrier or voice frequency repeaters or loop extenders which may be either field or central office mounted.

2.17 When estimating the probability of lightning damage to telephone plant, several variables must be considered. Briefly, they include:

2.171 Storm frequency or incidence. The measure of storm frequency is the number of "thunderstorm days" experienced at a given location during a year. A "thunderstorm day" is defined as any day during which thunder can be heard at the location in question. Figure 4, is a chart of storm frequency for the United States.

2.172 Earth Resistivity. The electrical resistivity of the earth (resistance of the earth to the flow of current) is of almost as much importance as the intensity and frequency of occurrence of lightning strokes in determining the probability of lightning damage. The unit of earth resistivity, the meter-ohm, is defined as the resistance, in ohms, between opposite faces of a cube of earth one cubic meter in volume. An alternate measure, the ohm-centimeter, is defined as the resistance, in

ohms, between opposite faces of a one cubic centimeter cube of earth. To convert meter-ohms to ohm-centimeters, multiply the former by 100. If earth resistivity is high, the voltage which a given stroke would develop across a dielectric, and the distance that lightning currents would travel along a conductor before attenuating to harmless values are greater than if the earth resistivity is low. The result is that the probability of lightning damage is greater in some parts of the country with high earth resistivity and only moderate incidence of storms, than it is in other parts with low resistivity and greater incidence. Earth resistivity varies over a considerable range in the continental United States; from a few meter-ohms along part of the coast of the Gulf of Mexico to 10,000 meter-ohms or more in upland or mountainous country. Table I gives ranges of earth resistivity values to be expected for various soils.

TABLE I: RESISTIVITY OF VARIOUS SOILS

SOIL	RESISTIVITY RANGE (M-Ω)
Loam	5 - 50
Clay	4 - 100
Sand/Gravel	50 - 1,000
Limestone	5 - 10,000
Shale	5 - 10,000
Sandstone	20 - 2,000
Granite	1,000
Slates	600 - 5,000

2.173 By combining data on storm frequency and earth resistivity, a lightning damage probability map (Figure 5), has been devised. It should be noted that this map is intended as a broad guideline indicating areas in which greater than average lightning damage can be expected.

2.174 Local Experience. While Figure 5 is valuable for determining if broad areas may experience more than average lightning problems, local experience will show many exceptions to these guidelines. A microwave tower on a hilltop in a low lightning damage area may require special protection while customer stations in a city of tall buildings located in a problem area, and served by cable in duct runs, may require only minimal protection. Setting rigid standards for the evaluation of local experience is impossible. Good engineering judgement, based on the best available experience and information, must be exercised to obtain optimum protection for the system under consideration.

2.18 Electric power supply lines which cross over or are in conflict with telephone lines may produce hazards and damage to telephone plant by means of a "power follow arc" between the lines. High voltage due to lightning on a power line may produce ionization of the air which

may result in the establishment of a "power follow arc" between the electric line and an adjacent telephone line. Once this arc is established it may be sustained by the power circuit voltage even after the lightning disturbance has disappeared. An arc of this type, remaining even for a short interval, may result in considerable damage to telephone plant. To minimize or avoid such damage, adequate separations between the power and telephone lines must be maintained.

2.2 Electric Power Supply Lines

2.21 The possibility of damage to telephone systems due to accidental contacts between electric power supply lines and aerial telephone lines is an important hazard requiring protection measures. The most common causes of these accidental contacts are: lack of adequate care in installing telephone facilities on joint use lines, falling tree limbs, improper sagging of conductors, damage to power or telephone plant by the public, structural failures, poor maintance, sleet and wind storms, and conductor failure due to burns from lightning. These contacts may occur at crossings, underbuilds, in joint construction, and where power supply and telephone lines are paralleled with inadequate separation. The National Electrical Safety Code (ANSI C2) provides information on minimal separation and construction, and should be consulted when joint use, close parallels with power lines, or crossings are being constructed. Due to the decrease in aerial plant construction, the type of construction most vulnerable to this problem, damage due to power contacts is decreasing.

2.211 One area where power contacts may become more of a problem is the joint random separation of buried facilities. In this situation, should a dig-in take place, (for example, a sewage company's trenching machine digs through the power and telephone cables) there is a likelihood that the telephone facilities may become energized.

2.22 Two steps should be taken to avoid power contact or follow arc hazard The first is to design, construct, operate, and maintain the power and telephone lines in such a manner that adequate separations, where possible, and mechanical strengths are achieved. The second step is to coordinate the protective equipment of the two systems to insure prompt deenergization of the power line in the event of a contact.

2.23 With power systems having a ground connection at the substation such as is normally the case with "wye" connected substation transformers, a line fault to ground involving a contact with properly protected telephone plant will cause a fault current to flow and will usually open the power system overload protection equipment. In the case of a common multi-grounde neutral (MGN) type of power system 1/ prompt deenergization of the power circuit can usually be assured in the event of a contact with telephone oper

1/ A common multigrounded neutral (MGN) electric power supply system is a "Wye" connected system which has solidly interconnected primary and secondary neutrals, and at least four grounds per mile of line in every mile of line, exclusive of grounds at customer's premises.

wire or cable plant by grounding telephone protection devices to the MGN.

With a non-grounded (delta) system, the current through a single contact with telephone plant is substantially the charging current of the metallically-connected power network through a single-phase fault to ground. This current is proportional to the normal power voltage to ground and to the total line mileage (three-phase basis) of the metallically-connected power network. Involvement of REA-financed telephone plant with delta systems will be mostly with the lower voltage systems (4.2 kv or below) which because of the low voltage are of relatively short lengths. Hence in these cases, the current in the telephone plant will be small and of no significance from the plant hazard standpoint. The maximum voltage from the telephone plant to ground at the point of contact,--significant as regards hazards to linemen--is proportional to this current and to the impedance of the telephone plant to ground as seen from the point of contact. Again, at power voltages of 4.2 kV or lower, this voltage will hardly be high enough to constitute a hazard. However, occasional cases may occur in some parts of the country where contacts are possible with delta systems at higher voltages and of greater mileage. Such cases may require special attention from the standpoint of telephone plant voltage to ground from a single contact, especially where the telephone plant impedance to ground is high (as with high protector ground resistance). But even here the currents in the telephone plant are so small that hazards to plant or other property--as distinguished from possible hazards to persons--are negligible. Power system protective devices such as pole-top reclosers, fuses, etc., would, of course, not be operated. Even where no material hazard is created by the single contact, noisy conditions in the telephone system will ordinarily call attention to its existence although the power system will not be made inoperative and power operating personnel may be unaware of the condition, at least for some time after it occurs.

2.241 When a double fault to ground occurs on a delta system with one of the two faults to telephone plant, practically the full phase-to-phase voltage may be impressed on the telephone plant but the ability to deenergize the power system will be limited by the resistances of the two ground connections. Protection against single faults to ground (involving contact with telephone plant) on unigrounded wye systems with ground relaying, and on delta systems equipped with wye-connected grounding banks and ground relaying, can be achieved in some instances by equipping open wire telephone line with power contact protectors grounded to ground rods. Aerial cable plant can usually be protected in similar circumstances by grounding the support strand to driven ground rods at frequent intervals. The chances, however, of achieving satisfactory coordination are still much poorer than in the case of MGN systems. For the above reasons, coordinated protection at crossings and in joint use with other than MGN systems is difficult to achieve and safety is largely dependent on mechanical strength. <u>In view of these considerations, joint use with other than MGN power systems should be avoided wherever practicable.</u>

2.242 Buried, rather than aerial, plant should be considered when joint use construction with non-multigrounded neutral types of power systems is necessary. If aerial plant must be used under these conditions, a study of local grounding conditions and the power system characteristics should be made by the borrower's engineer to determine if there are any practical means of obtaining coordinated protection. The REA field engineer should be contacted for advice.

2.3 Low Frequency Electric 2/ Induction from Electric Power Supply Systems

2.31 When telephone circuits are in close proximity to alternating current power lines, a voltage (which is sometimes called an electrostatic voltage) appears on the telephone wires as a result of the electric field surrounding the power conductors; this field being due, in turn, to electric charges on the power wires. Under normal conditions, the electrically induced voltage on telephone cable conductors is limited to a very low value by drainage provided by cable shielding and the central office line termination. Cable capacitance and central office line terminations are also effective in holding electrically induced voltage to a reasonable level on open wire conductors which are extended from a cable. However, if open wire circuits are disconnected from the cable or central office for any reason, and also where the open wire lines are long, the induced voltage on these open wire circuits may be hazardous and therefore, require reduction. In some instances its open-circuit value may be in excess of 800 volts to ground. The possibility of injury to persons--linemen in particular--in contact with a wire subject to this induced voltage does not depend upon the open circuit voltage but upon the current drawn through the circuit. This current is so small (due primarily to the poor regulation characteristics of the capacitive coupling between the power and telephone wires) that no serious hazard from electric shock as such is to be expected. Nevertheless, the shock, though it be mild in intensity, may have a surprise effect involving hazard to a man working on a pole. That is, the worker may be startled, release his hold on a tool or the pole as a reflex action, and either drop something on personnel below or fall from the pole. While the shock hazard is of primary concern, the induced voltage may also cause equipment damage or phenomena such as bell tapping or noise which are bothersome to subscribers, thus leading to trouble reports.

2.32 The proper methods of rectifying this problem are discussed in detail in TE & CM-820.

2.4 Low Frequency Magnetic Induction from Electric Power Supply Systems

2.41 When a phase wire of a grounded neutral power line is grounded, current flows from the source of power to the point where the ground occurs. A similar situation arises if two phase wires of a delta system or an isolated neutral system become grounded or short circuited. This fault

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2/ Though the relations depend upon electrostatic principles, the term "electrostatic" is not appropriate for this situation due to the continously varying field which is involved.

current, in either case, increases the magnetic field about the power lines involved, and the increased magnetic field in turn increases the induced voltage in paralleling telephone circuits. The magnitude of the induced voltage is proportional to the fault current and the degree of coupling involved. If a parallel at close separation exists between the power and telephone lines, the coupling effect is relatively high. If, in addition, the fault current is high, the induced voltage may be of sufficient magnitude to be dangerous to linemen working on the telephone line when the power fault occurs and it may also produce hazards to the public, acoustic shock, and damage to plant. If the induced voltage exceeds the breakdown of station protectors, it is probable that many station protectors may become permanently grounded. With unusually high capacity power transmission lines it is possible to have excessive induced voltage with normal conditions on the power line. Because of such possibilities, long parallels with power lines having high fault currents and with high capacity transmission lines should be avoided or kept to a minimum. If unavoidable, special protective measures as described in Section 825 are available and should be provided.

2.5 Low Energy Static Sources

2.51 In some areas open wire lines are subject to excessive static potentials through wind blown sand or snow. Such potentials are low in energy, which is proportional to the capacitance between line and earth and therefore, proportional to the length of the lines involved. The resulting interference effects are entirely in the category of circuit noise, mainly due to intermittent breakdown of protective devices. Remedial measures for open wire lines are discussed in TE & CM-820.

3. REMEDIAL MEASURES

3.1 Disposition of the harmful effects arising from extraneous over voltages and currents is achieved in one of three ways:

3.11 Separation or isolation of the telephone plant from the interfering source.

3.12 Diversion of the elevated potentials and currents to earth through by-passing protective devices operating at tolerable potentials. Examples of such devices include gap type, or other voltage limiting, arresters.

3.13 Prevention of the over-heating effects of excessive currents by the use of fuses or other current limiting devices.

3.2 While it is obviously not practicable to isolate wire or cable plant from lightning effects, especially in rural areas, the degree of plant ...e may sometimes be reduced by selective routing. For example, where ...s a possibility, at comparable cost, of routing buried plant away from ...all trees or structures. Thus, the likelihood of arcing from these to the cable, or the development of conducted currents to telephone be reduced. Where routing of plant through a valley

is feasible rather than over adjacent high elevation the former will result in some reduction of lightning exposure. Another form of isolation is achieved in special circumstances (See TE & CM-825) by the use of an isolating transformer to avoid currents to ground at terminations. Still another means of isolation is sometimes provided by the production of neutralizing potentials to avoid the effects of low frequency power system voltages.

3.3 The traditionally accepted device for limiting extraneous voltages is the air gap arrester--a device employing two electrodes separated by an air gap, and connected as bypass or shunt around the system to be protected. By adjusting the separation between electrodes, the value of permitted potential is controlled. A modification of the air gap arrester consists in the enclosure of two electrodes in a gas usually at reduced pressure, thereby permitting wider separation between electrodes with reduced liklihood of permanent short circuiting of the gap. Other potential limiting devices are solid state units such as Zener diodes or varistors, having a non-linear voltage-impedance characteristic such that potentials are limited by a rapid increase in conductivity at critical voltage levels.

3.4 Fuses or circuit breaker devices are employed only in special cases to interrupt low frequency currents where the bypass or arrester device used to limit potentials would otherwise become a fire hazard in themselves. Current limiting devices are never used as an auxilliary to lightning bypass devices.

4. COMMONLY USED PROTECTION DEVICES

4.1 Voltage Limiting Devices

4.11 The general category of voltage limiting devices includes not only gap devices, such as air gap carbons and gas tubes, but also solid state units such as zener diodes and varistors. The voltage limiter appears as an open circuit until a threshold or breakdown voltage is reached. At this point the device changes to a conducting mode and provides a low impedance shunt across the terminals it is protecting. In this manner voltage across a load in parallel with the voltage limiting device will be restricted to approximately the voltage limiter's threshold voltage.

4.12 Perhaps the most common category of voltage limiting devices in the typical telephone system is the gap type arrester, such as the carbon block, which employs the dielectric breakdown of an air gap as a means of providing the low impedance shunt. The gap type arrester will generally handle more energy than solid state devices of equivalent cost. Unfortunately, it is difficult to produce gaps with extremely low breakdown voltages. Also, by its nature, the gap provides a broad range of probable breakdown voltages, frequently ± 25% from the nominal. In some instances these limitations may make the gap useless without additional supplemental protection, while in others they may not matter and the gap will be the most economical means of protection.

4.121 Carbon block air gap arresters are available in a number of breakdown ranges, and are color coded as shown in Table 2.

TABLE 2: CARBON BLOCK ARRESTER COLOR CODES

COLOR CODE	NOMINAL DC BREAKDOWN VOLTAGE RANGE
White	350 - 600
Blue	500 - 1,100
Yellow	700 - 1,400

The primary objection to the carbon block form of arrester is the high maintenance associated with low breakdown voltage units. When a small gap is employed, there is a tendency for carbon particles to become lodged in the gap, thus permanently grounding the unit and disabling the circuit. When larger gaps can be employed, permanent grounding only occurs infrequently.

4.122 An arrester assembly from a carbon block station protector, as shown in Figure 6, is an excellent example of fail-safe gap type protection. The cylindrical electrode is recessed a few thousandths of an inch from the top of the ceramic insulator so that when the unit is assembled an isolation gap exists between the carbon disk and cylindrical carbon. This is the air gap that must be broken down for the unit to provide a low impedance path to ground. In the event of a long duration energization, such as from a power contact, cement between the ceramic insulator and cylindrical carbon softens, permitting the carbon to slip, under spring pressure, and close the gap. If energization continues beyond this point, the generation of heat within the unit melts the fusible pellet, permitting the cage to slide completely over the ceramic insulator and contact the mounting base electrode, thus providing a metallic by-pass around the carbon electrodes.

4.13 Gas tube arresters, covered in detail in TE & CM-823, are gap electrodes in a sealed atmosphere of inert gas. In general, maintenance of gas tubes is lower than that for carbon block protection, however, the initial cost of the gas tube arrester is considerably higher than for the carbon block arrester. As a result, REA recommends the use of gas tubes in only the following situations:

4.131 High priority circuits where service continuity is essential (e.g.--fire alarm circuits).

4.132 All carrier circuits.

4.133 Circuits with a record of repeated grounding of carbon blocks.

4.134 At remote protector locations, in high lightning areas, where maintenance calls would be difficult and expensive.

4.14 At present, due to their relatively high cost and comparatively low energy handling ability, solid state voltage limiting devices are in very limited use within the telephone industry as main energy handling, or "primary" protection. The foremost use of these devices is as low voltage "secondary" protection for electronic equipment, as covered in TE & CM-822. Due to the solid state devices' relative insensitivity to surge rate of rise, and its ability to furnish a precise, low breakdown voltage, these units are invaluable for protecting delicate electronic components from electrical over-loads.

4.2 Current Limiting Devices

4.21 The fuse, such as used in a fused type station protector is probably the prime example of this class. It should be noted, however, that other devices, such as the fuse link, circuit breaker, and heat coil are also current limiting devices. The current limiting device appears as a short or low impedance until excessive current is forced through it. When this happens it opens the circuit and isolates the equipment being protected from the line. Since most current limiting devices are thermally activated, there is a significant delay before the device operates. Figure 7, illustrates the time versus current curve for a typical self-resetting circuit breaker. While this device is slow compared with most fuses, it provides an excellent illustration of what the protected device must withstand before this form of protection will operate.

4.22 The fused type station protector, as shown in Figure 8, illustrates one method of reducing current passing through the protected load while still causing fuse operation. It is essential that fuse type station protectors be connected in this manner, with the fuses between the line and the arresters so that operation of the arresters provide current paths to ground for operation of the fuses.

4.23 Fuseless station protectors in preference to fused protectors are strongly recommended by REA where ever the National Electrical Code (NEC) requirements can be met. These requirements are set forth in Article 800 of the NEC. Fuseless protectors, when properly installed provide equivalent voltage limiting to fused protectors, but must be connected in series with a fuse link consisting of a short length of wire-usually 24AWG copper-instead of a cartridge fuse. The 24AWG fuse link has a time-current fusing characteristic what is equivalent to about a 30 ampere fuse instead of the 7 ampere unit used in fused type station protectors. As a result, the fuseless protector should require much less maintenance. Because much greater energy is required to open the 24AWG fuse link than is required to open the 7 ampere fuse, the current carrying parts of fuseless station protectors must be capable of handling relatively large amounts of energy without becoming a fire hazard. This capability is provided by a metallic

by-pass consisting of the cap, spring, cage, and melting of the fusible pellet shown in Figure 6. The advantages of fuseless station protectors, and the disadvantages of fused station protectors are discussed in TE & CM-805.

4.24 Heat coils are not fuses, but may be connected in series between the line and the line circuit equipment of the central office. Abnormal current through the winding of the heat coil generates heat which softens a soldered connection and permits a spring to open a set of contacts and isolate the equipment from the line circuit while optionally grounding the energized outside plant conductor. Tests conducted by REA have shown the heat coils are generally not effective in protecting modern switching equipment because they are not sufficiently sensitive. In most cases, the energy required to operate the heat coil results in current through the line circuit equipment which will damage the equipment prior to heat coil operation It is not practical to make the heat coil more sensitive, so the use of heat coils is not recommended as they represent a possible source of noise as well as an unnecessary cost with no engineering benefit. Heat coils were dropped from the COE contract in 1963. (See TE & CM-810).

4.3 Other Protection Devices

4.31 While the items covered in Paragraph's 4.1 and 4.2 are the most frequently used protection devices, other items exist whose application is important to comprehensive protection of a telephone system. Several of the more important examples are as follows:

4.32 Neutralizing Transformer. The principle of the neutralizing transforme is to produce induced potentials in the telephone conductors equal in magnitude and opposite in polarity to the potentials caused by power line induction or a ground potential rise at a power station. The two ends of the primary winding are connected to the ground at different locations so that the voltage to be neutralized appears across this winding. Secondary windings having a 1:1 ratio to the primary are connected in series with the telephone circuit conductors in such a way that the potentials induced from the primary are opposed to and approximately equal to the foreign potential. Use of the neutralizing transformer for electrical protection is covered in detail in TE & CM-825. Neutralizing transformers might also be used for noise control in some situations. Data on this application will be covered in the 400 series of the TE & CM.

4.33 Drainage units. Drainage units usually consist of inductor-capacitor networks connected from each side of the line to ground. Drainage units are designed to reduce electrically induced voltages in open wire telephone circuits with a minimum of disturbance to the communications signals. Electrically induced voltages are caused by capacitive coupling between a power supply line and a telephone line. The application of these units is covered in TE & CM-sections 820 and 825.

4.33 Isolating Transformer: The isolating transformer is simply a 1:1 transformer with high dielectric capability which "isolates" the station terminal equipment from the remainder of the communications facility. Thus the station terminal is free to "float" with the local ground without feeding excess voltage back into the communications facility.

4.331 Isolating transformers are generally less expensive and more compact than neutralizing transformers. They are available with dielectric withstand capability from 1000V to approximately 25KV and insertion losses of approximately 1dB at either voice or carrier frequencies, depending on the transformer selected. One shortcoming of the isolating transformer is that it does not provide dc continuity. The use of isolating transformers is discussed further in TE & CM-825.

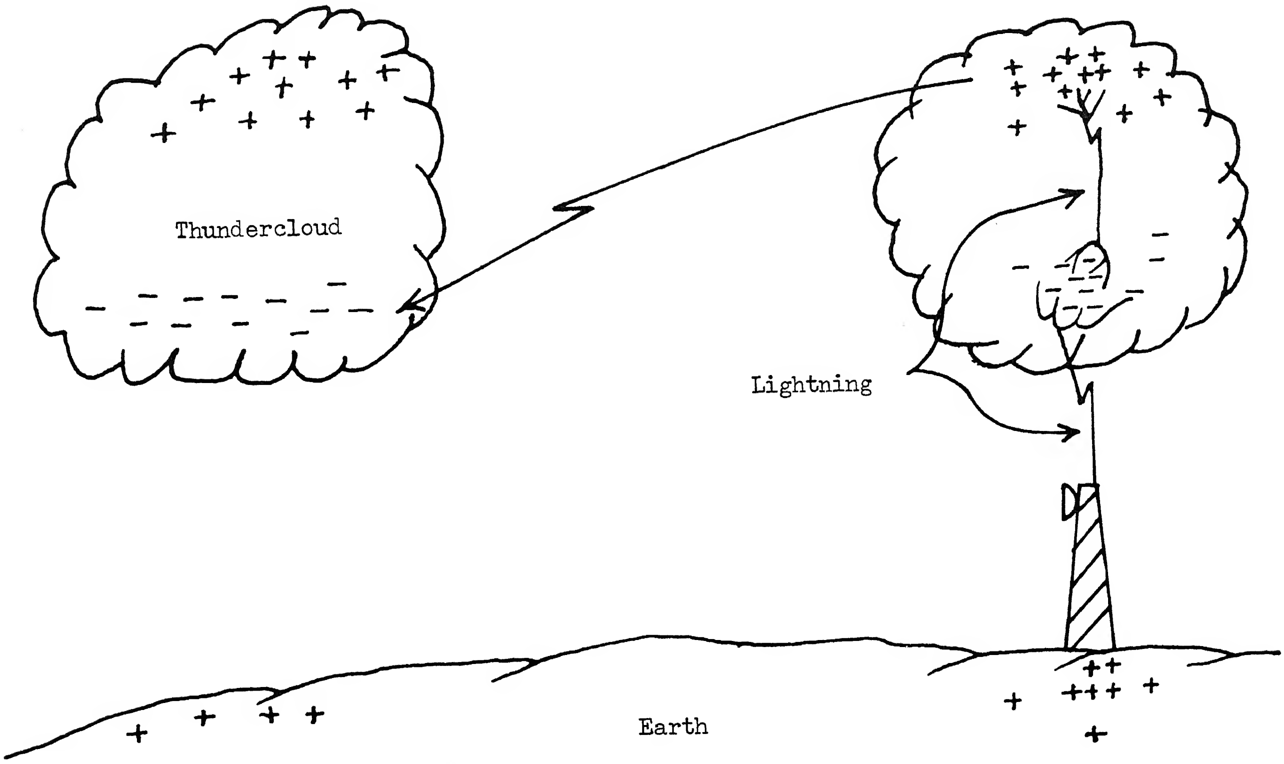


FIGURE 1: Source of Lightning

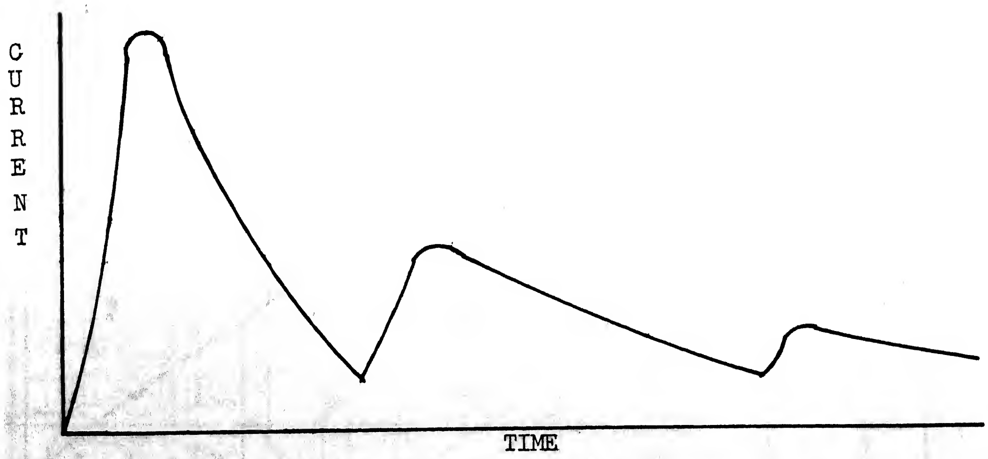


FIGURE 2: Current Time Plot of a Lightning Discharge

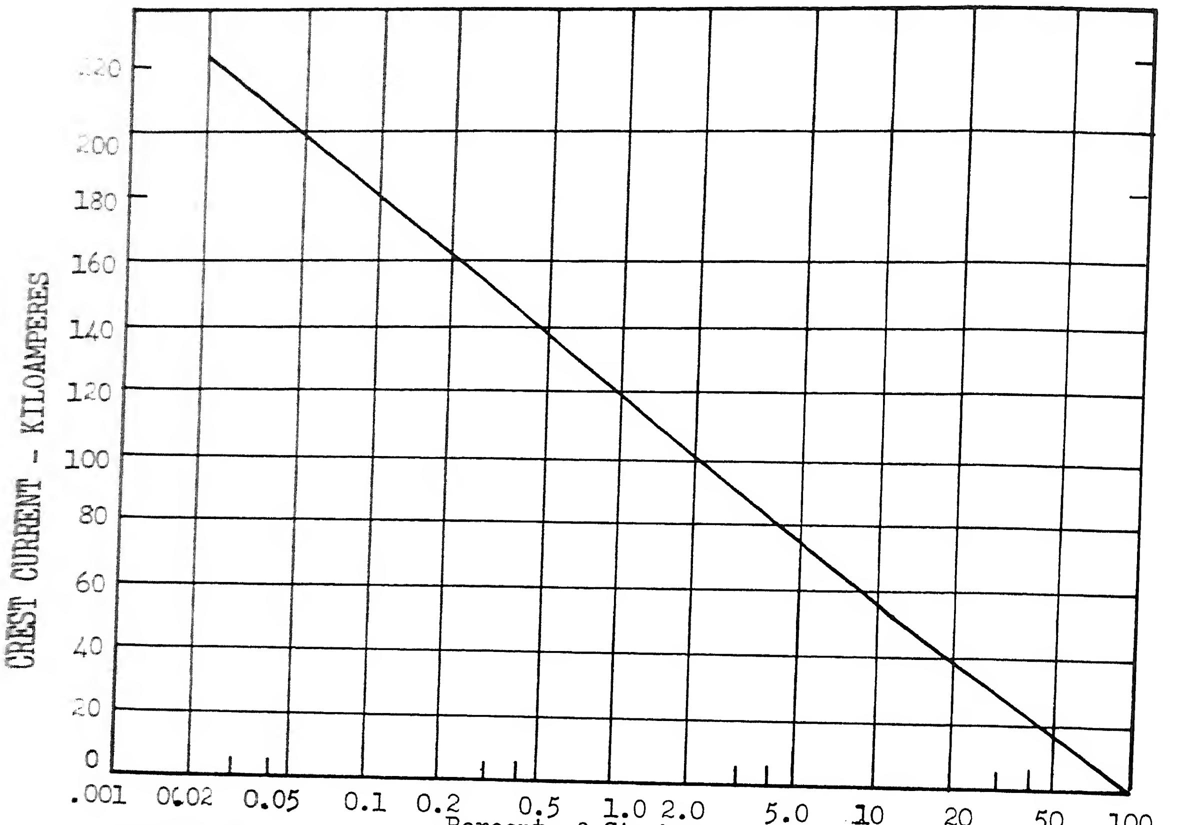


FIGURE 3A: Distribution of Lightning Stroke Crest Currents to Aerial Structures

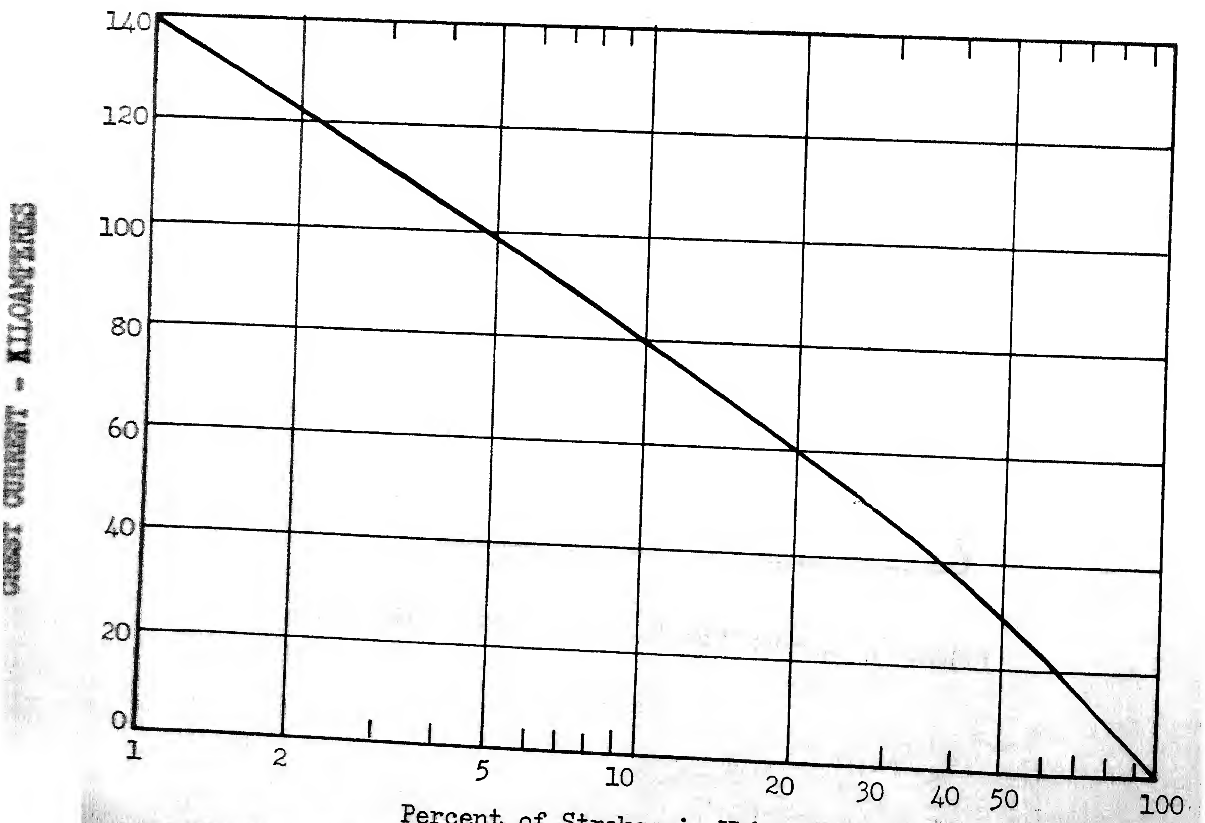
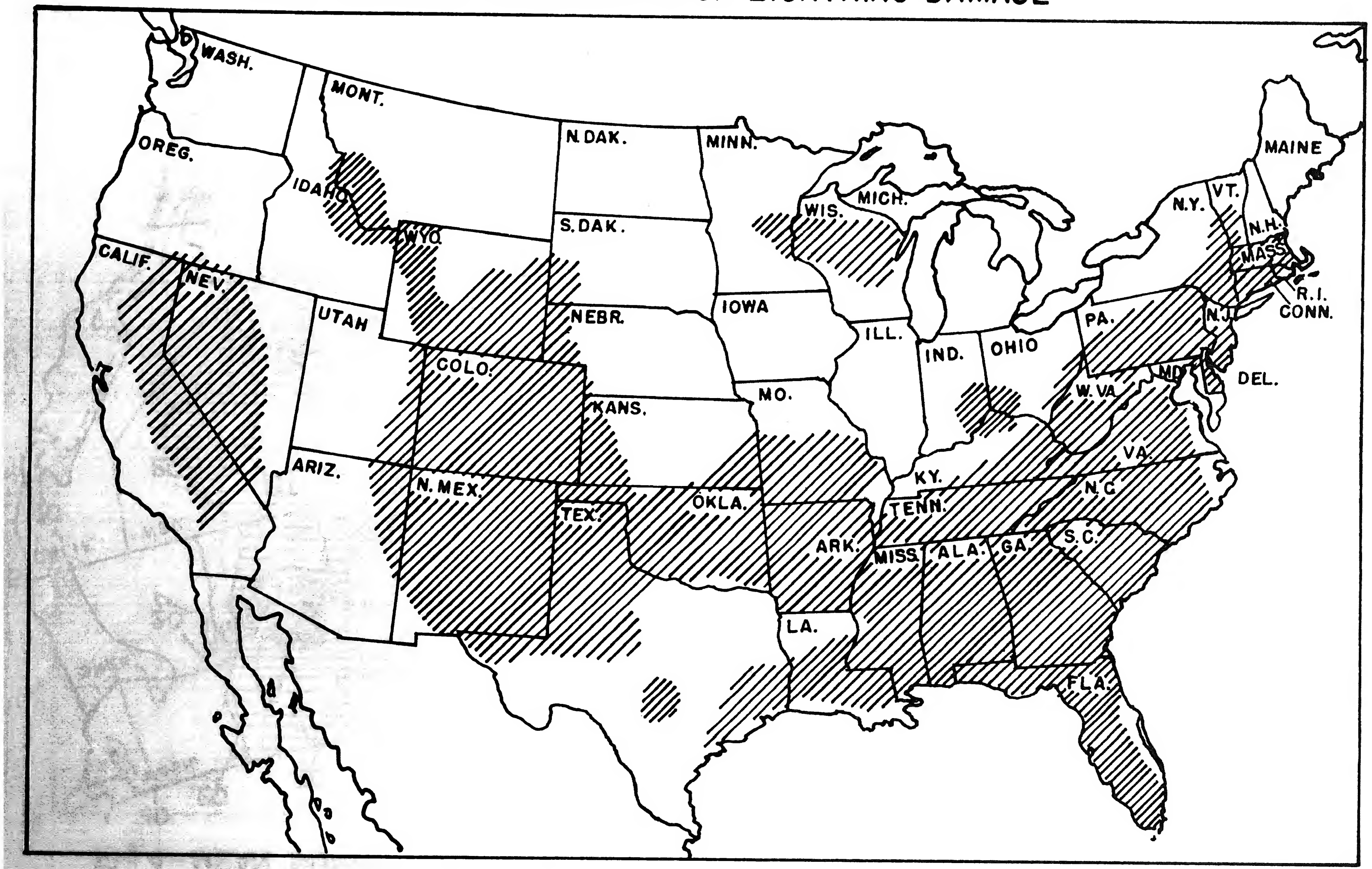


FIGURE 3B: Distribution of Lightning Stroke Crest Currents to Buried Structures

Fig. 5 - LIGHTNING DAMAGE PROBABILITY MAP - SHADED AREAS INDICATE A GREATER THAN AVERAGE PROBABILITY OF LIGHTNING DAMAGE



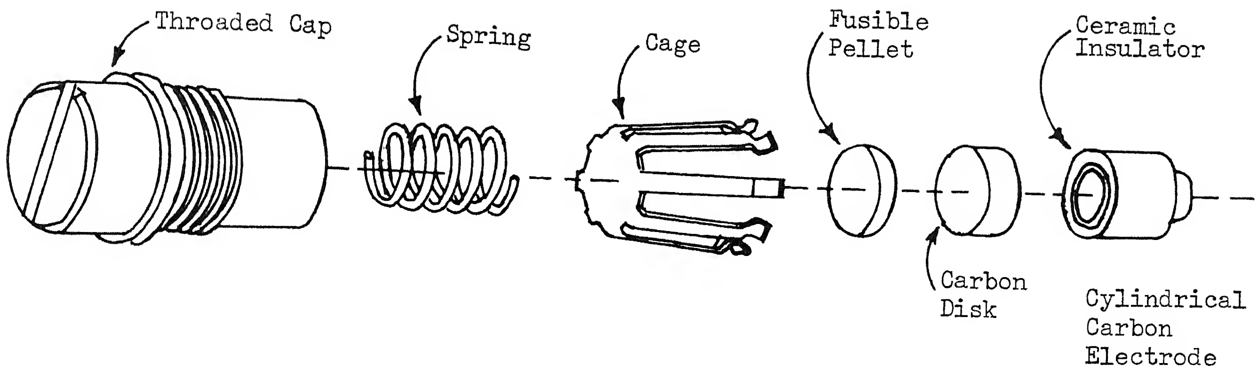


FIGURE 6: Exploded View of Arrester Assembly

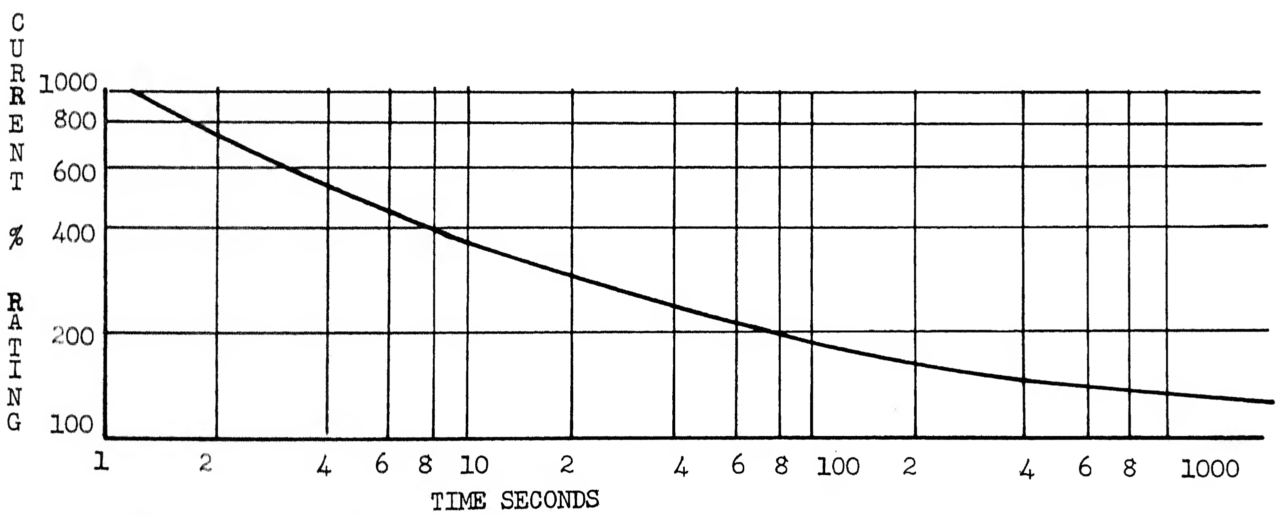


FIGURE 7: Circuit Breaker Trip Delay

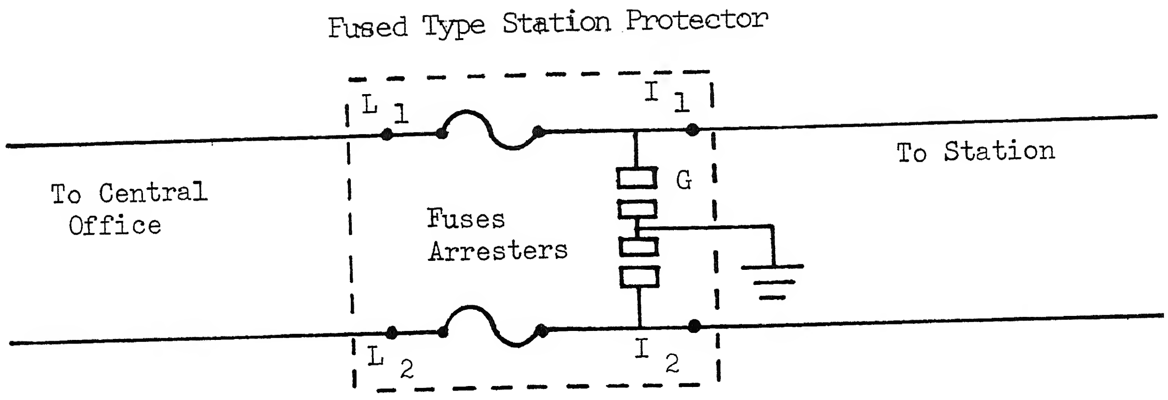


FIGURE 8: Installation of Fused Type Station Protector